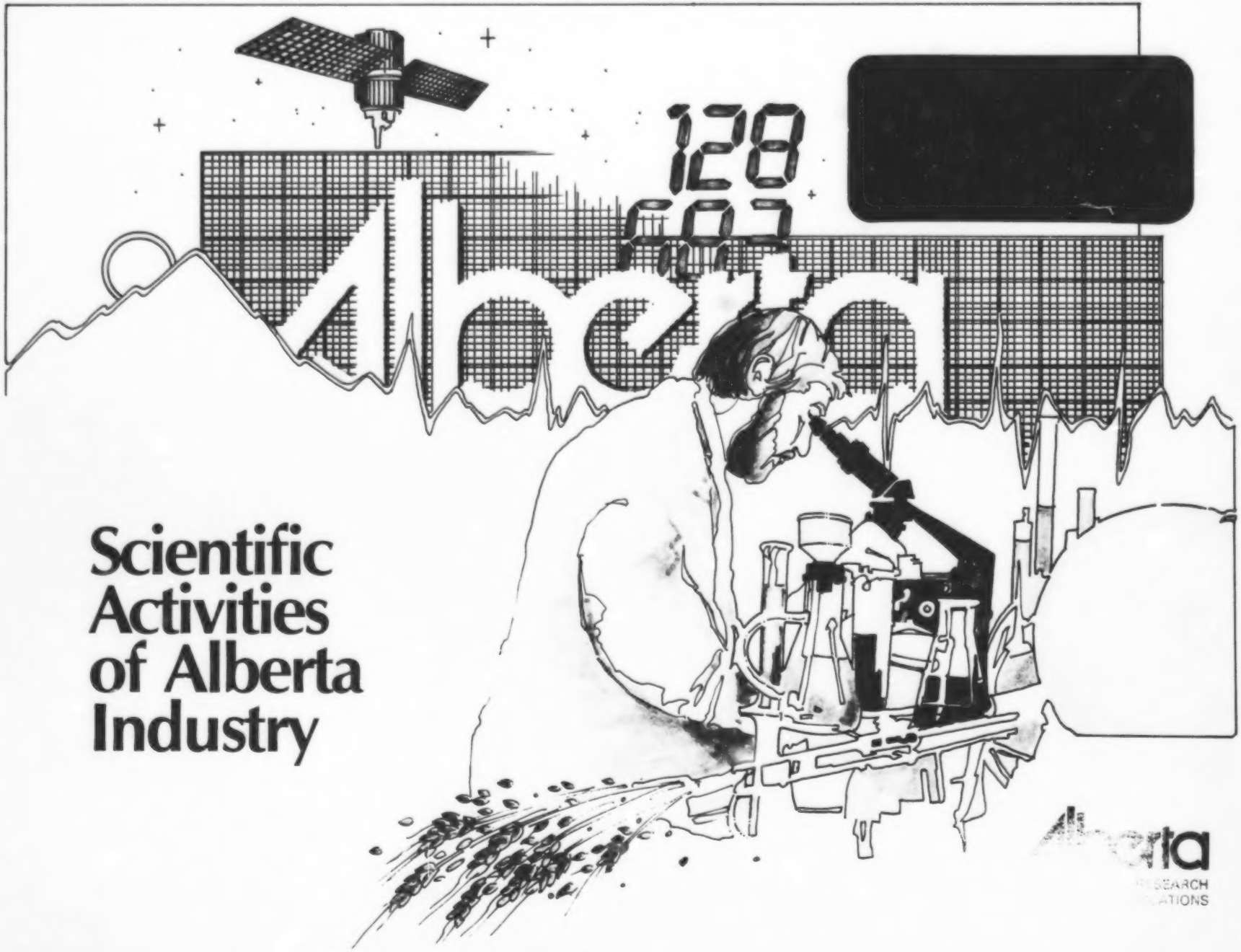

Scientific Activities of Alberta Industry

INDUSTRY R&D
1986

INTRODUCTION

This survey reports on industry performed research and development in the natural sciences and engineering fields. It is different from the companion surveys of Federal and Provincial Governments which are reports from funders and cover an array of scientific activities in the social sciences as well as the natural sciences.

The results of the 1986 survey of industry R&D are based on the reports of 3,414 companies which encompass about 3,700 research units. Among this year's participants are 2,000 first time respondents and 555 respondents to past surveys. The remainder are some of the firms that received federal research grants and contracts or claimed science tax credits, about 40% of these two groups are represented in the survey. Of the 6,900 companies approached by Statistics Canada, 2,300 performed no R&D in '86.

Of the 3,414 companies performing R&D, a few did a lot: 25 companies (less than 1%) accounted for half of the dollar value of industry R&D. The number of major performers/spenders is small: 13 companies spent over $50 million on R&D; 21 spent over $25 million; 105 spent over $5 million.

The diversity of industries represented by the survey is reflected in Table I which groups respondents by Standard Industrial Classification (SIC). Note that the service industries comprise about 45% of the reporting units. The table also provides information on the size of the firms. The majority of R&D performers have less than 100 employees. The largest firms (over 500 employees) make-up varying proportions of the industry groups: in mining and oil wells, large firms constitute 40% of participants, 11% of the manufacturing group, four % of the services group.

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TABLE I
1986 R&D Performers by Industry (SIC) and Employment Size

Industries	Performers	Employment (person years) 1-99	100-499	< 500
Mining and Oil Wells				
Mining	32	14	4	14
Crude Petroleum & Natural Gas	24	11	5	8
TOTAL Mining & Oil Wells	**56**	**25**	**9**	**22**
Manufacturing				
Food, Beverages & Tobacco	151	75	38	38
Rubber & Plastic Products	79	53	20	6
Textiles	36	11	18	7
Wood	31	18	10	3
Pulp & Paper	38	8	13	17
Primary Metals (ferrous)	14	3	5	6
Primary Metals (non-ferrous)	12	3	4	5
Metal Fabricating	166	124	33	9
Machinery	267	204	55	8
Aircraft & Parts	18	8	3	7
Other Transportation Equipment	80	36	23	21
Telecommunication Equipment	24	17	4	3
Electronic Parts and Components	60	41	17	2
Other Electronic Equipment	101	78	13	10
Business Machines	78	60	11	7
Other Electrical Products	102	64	26	12
Non-metallic Mineral Products	34	23	5	6
Refined Petroleum & Coal Products	18	11	-	7
Drugs & Medicines	57	29	22	6
Other Chemical Products	163	99	42	22
Scientific & Professional Equipment	103	90	11	2
Other Manufacturing Industries	172	125	41	6
TOTAL Manufacturing	**1,804**	**1,180**	**414**	**210**
Services				
Transportation & Other Utilities	46	15	8	23
Electrical Power	11	1	1	9
Computer Services	346	327	14	5
Engineering & Scientific Services	535	504	28	3
Other Non-manufacturing Industries	616	537	53	26
TOTAL Services	**1,554**	**1,384**	**104**	**66**
TOTAL ALL INDUSTRIES	**3,414**	**2,589**	**527**	**298**

One further point needs to be made regarding the geography of the survey, shown in Table II. The majority of responding units are based in Ontario (44%) and Quebec (23%). Alberta firms appear to be under-represented based on the Department's database, Altatech, which monitors research activities of the commercial advanced technology sector. Cross-referencing the Altatech and survey populations confirms a significant under-representation. Technology, Research and Telecommunications is co-operating with Statistics Canada to improve coverage of Alberta industry R&D in the 1988 survey.

TABLE II
Location of Reporting Units in the 1986 Survey

Province/Region:	Units
Atlantic	156
Quebec	1,624
Ontario	853
Manitoba	99
Saskatchewan	129
Alberta	354
British Columbia	467
Territories	7
TOTAL	**3,689**

NATIONAL RESULTS

The dollar value of industry R&D in Canada has risen consistently since the mid-70s. Between 1981 and 1986, intramural R&D expenditures have increased 80% from $2,125 million to $3,828 million. The upward trend in industry R&D is equally impressive when expressed in constant (1981) dollars: 1986 expenditures were equivalent to $3,055 million, a 44% increase.

As shown in Table III, this trend was fuelled by the service industries in which R&D expenditures jumped 246%. In contrast, the mining and oil wells industries reduced their spending by 34%. Over the six-year period, there has been a notable shift in the composition of industry R&D. The manufacturing industries performed the majority of R&D, 71% of the '86 total compared to 80% in '81. However, the services sector accounted for 26.5%, up from 14% in '81, while mining and crude petroleum industries accounted for two % in '86, down from six % in '81.

TABLE III
Dollar Value of R&D Performed by Industry According to Sector for 1981 and 1986

Sector	1981	1986	% change
	($ in millions)		
Mining & Oil Wells	131	86	-34
Manufacturing	1,700	2,724	60
Services	294	1,018	246
TOTAL	**2,125**	**3,828**	**80**

SOURCES OF R&D

The research performed by industry is largely funded by industry. For this year, $2,464 million of the value of industry research was provided by the performing companies. Federal government grants and contracts contributed 11% ($409 million) as did provincial governments and other Canadian sources ($440 million). Foreign sources supplied a slightly higher percentage at $515 million.

There is considerable variation among industries in the level of intramural funding. Consider the main research intensive industries shown in Table IV. Firms in the refined petroleum and coal industry provided 95 cents of every R&D dollar; in the engineering and scientific services industry, firms supplied 34 cents of every R&D dollar. Federal support to manufacturing was concentrated in the aircraft industry, contributing one third of its total '86 expenditures. Provincial governments and other Canadian sources were significant sponsors of crude petroleum and natural gas industry R&D (57%), computer services and engineering and scientific services industries R&D (33%). Foreign sources added significantly to the business machines sector within the electronics industry, supplying about 50% of its total expenditures. Note that foreign controlled companies in this sector performed nearly 90% of the R&D.

TABLE IV
Source of Funds for R&D of Research Intensive Industries, 1986

Industry	Source of Funds ($ in millions)				
	Total R&D	Performer	Federal Govn't	Other Canadian	Foreign
Telecommunications	621	328	6	X	X
Aircraft	368	217	125	8	18
Electronics*	548	311	75	24	136
Refined Petroleum	147	140	X	5	X
Drugs & Medicines	103	84	2	8	4
Other Chemicals	162	145	5	1	16
Engineering	313	106	60	108	39
Electrical Power	180	134	35	X	X
Computer	198	115	17	65	2
Crude Petroleum	37	15	X	21	X
Mining	49	39	X	3	X
TOTAL	**3,828**	**2,464**	**409**	**440**	**515**

X not disclosable by Statistics Canada
* composite of electronic components and parts, other electric equipment, and business machines

CURRENT R&D

A common practice among science and technology statisticians is to declare that absolute dollar expenditure is the single, most valid indicator of R&D capacity but then go on to talk about relative measures of R&D. Two such measures are to relate R&D expenditures to annual sales and to separate capital from current expenditures. Current expenditures refer to wages and consumables of the R&D staff and is taken as an indicator of industry commitment to R&D. Capital expenditures cover buildings, site preparation, purchase of major research equipment, investments that tend to fluctuate. Table V captures these measures for the main R&D intensive industries.

There are two general patterns in the Table V data. For the manufacturing and service industries, '81 to '86 has been a period of sustained growth in absolute and relative terms. With regard to actual expenditures, the computer and engineering services industries had the highest average annual growth, 50% and 31%. Among the manufacturing industries, the electronics and business machines industry led at 24%, followed by the telecommunications equipment industry with an 18% average annual growth rate. These industries plus the aircraft industry comprise the top five performers of research in 1986.

A different trend is exhibited by the refined petroleum and coal, mining, and crude petroleum industries - one of declining absolute expenditures. Refined petroleum is the only manufacturing industry in Table V with a negative average annual change, about 12%. Total expenditures of the crude petroleum and natural gas industry contracted from $80 million to $37 milion, an average annual decline of 8.6%. The mining industry had a less dramatic change, a decrease of 0.5% annually.

For several of the manufacturing and service industries the rise in total expenditures is matched by an increase in the percentage of annual sales revenue directed to current R&D expenditures. This is particularly notable in the telecommunications, aircraft, and engineering services industries, the group that has consistently applied over 10% of revenues to current R&D. A sharp contrast is the trend in the energy related industries, i.e. refined petroleum and coal, electrical power services, and the mining group of industries. These industries allocate a constant one % or less to current R&D. The data suggests that an expansion of R&D capacity has occurred in the telecommunications, aircraft, engineering services, and computing services industries while the energy related industries have maintained about the same R&D capacity.

TABLE V
Time Series of Total, Capital and Current Research Expenditures for Technology Intensive Industries

Industries	1981	1982	1983	1984	1985	1986	
Telecommunications Equipment	275	349	457	528	611	621	Total R&D $ in millions
	18.9	16	21.6	24.2	22.7	14.6	% capital to total R&D
	9.2	11	13.2	15.5	16.2	17.8	% current to sales
Aircraft	256	295	279	282	337	368	
	7	7.8	4.6	6	6.8	8.9	
	12.6	14.5	17.3	15.9	15.9	13.9	
Electronics	192	277	313	390	481	548	
	10.9	12	13.7	14	11.4	15.1	
	5.8	7.3	6.2	6	7.9	7.6	
Refined Petroleum & Coal	272	244	184	218	205	147	
	14.3	28	22	37	33	11.5	
	0.8	0.6	0.4	0.4	0.5	0.5	
Chemicals	95	122	115	132	164	162	
	15.7	19.6	13	12	17	11.1	
	0.9	1.1	1.1	1.2	1.3	1.4	
Drugs & Medicines	52	58	66	63	82	103	
	11.5	8.6	9	4.7	9.7	16.5	
	4.3	4.7	4.7	3.9	3	4	
Engineering & Scientific Services	81	105	143	206	281	313	
	11.1	7.6	11.1	16.9	14.5	18.5	
	7	11.9	13.4	12.1	20.9	22.8	
Electical Power Services	92	122	119	149	180	180	
	9.7	10.6	11.7	14.7	21	25	
	1	1.2	1	1	.09	0.9	
Computer Services	27	38	58	94	115	198	
	3.7	13.1	13.7	17	23.4	11.6	
	4.4	4.6	6.2	8.5	13.8	15.1	
Crude Petroleum & Natural Gas	80	85	49	67	69	37	
	34	38.8	32.6	23.8	33	8	
	0.6	0.6	0.6	0.8	0.6	0.6	
Mining	51	48	43	48	51	49	Total R&D $ in millions
	5.8	8.3	11.6	10.4	7.8	10.2	% capital to total R&D
	0.8	1.1	0.8	0.7	0.9	0.7	% current to sales

CAPITAL R&D

The capital expenditure data lends itself to two observations. The crude and refined petroleum industries' R&D is more capital intensive than any of the other industries. For most of the period, the crude petroleum and natural gas firms spent between 30% and 40% of their annual research budget on capital. Capital expenditures of comparable magnitude occurred in three of the six years in the refined petroleum and coal industry. The level and annual fluctuations in capital R&D are unique to the petroleum sector.

A second note is the level of capital spending by the service industries. The three service industries profiled in Table V show substantially higher capital investments in '86 over '81, most dramatic is the shift in computer services from $1 million to $23 million capital R&D.

TALENT POOL

Another indicator of R&D capacity and intensity is the size of the research labour force. Companies responding to the survey employed 24,530 professionals to perform R&D, augmented by technicians and others to comprise a research corps of 47,245 people. Wages for research staff amounted to $1,945 million, half of the total R&D expenditures. Table VI identifies the top 10 employers of research professionals, i.e. positions requiring a University degree.

The majority of the professional staff are people with a bachlor's degree. Researchers at the doctorate level are concentrated in the resource and chemical based industries. While the number of researchers may be small relative to other industries, doctoral level staff make up 25% - 35% of the research personnel in drugs and medicines, other chemical products, refined and crude petroleum, rubber and plastics, primary metals, and the pulp and paper industries. Electrical power services is the only comparable employer of doctoral level researchers.

TABLE VI
Top Ten Employers of Research Professionals in 1986 by Industry

Manufacturing Sector	Person Years	Services Sector	Person Years
Electronics	3,720	Transportation	1,280
Business Machines	1,572	Computing	1,460
Telecommunications	3,320	Engineering & Science	2,185
Chemicals	1,240	Electrical Power	725
Aircraft	2,145		
Other Transportation	715		

ALBERTA AND ENERGY

Energy R&D was performed by several industries: engineering and scientific services, electrical products, primary metals added to the research endeavours of electrical power, refined and crude petroleum, and mining industries. In all, 412 firms reported expenditures of $620 million on energy, spending $554 million in Canada. Energy research can be partitioned into five main concerns, each with special interests that can be associated with one or more of the performers. Table VII summarizes energy R&D for 1986.

TABLE VII
Energy R&D by Technology and by Funding

Technology	R&D ($ in millions)	Chief Source
Renewable resources	71	58 from service industries
•biomass	34	
•wind	18	
•solar, others	19	
Trans-mission/-portation	72	55 from service industries
•energy commodities	9	
•electricity	63	
Conservation	94	35 from mining and primary metals; 23 from service industries
•buildings	12	
•vehicles	20	
•industrial processes	55	
•other	7	
Fossil Fuels	251	164 from combined petroleum industries; 43 from service industries
•crude oil & gas:		
•exploration, production	63	
•enhanced recovery	13	
•oil sands:		
•surface mined	19	
•in situ production	56	
•refining	64	
•coal	36	
Nuclear	73	64 from service industries
•fuel exploration, mining	5	
•energy generation	69	

Aiberta has a particular stake in fossil fuels research. About half the value of the crude and refined petroleum industries R&D was performed in Alberta during 1981-1986. It is highly probable that a portion of the services industries R&D performed in Alberta was linked to fossil fuels research. Table VII shows the historical importance of the petroleum industries' to the provincial R&D capacity. At the start of the period, petroleum R&D constituted 84% of all industry research expenditures. 1986 is the only year in which the petroleum industries represented less than half of the total industry research in Alberta.

TABLE VIII
Alberta Industry R&D Expenditures by Special Industry Groups for 1981 to 1986

Industries	1981	1982	1983	1984	1985	1986
			($ in millions)			
Petroleum	235	206	130	130	145	89
Other Resources*	9	9	9	13	15	10
Manufacturing	14	27	30	35	40	41
Services	22	28	40	67	72	98
TOTAL	**280**	**270**	**209**	**245**	**271**	**238**

* includes mining, primary metals & minerals, and wood

1981 was the peak year for total Alberta industry R&D expenditures which declined by 15% in '86. Two factors appear responsible for the change in the total research volume. The first is decreasing expenditures by the petroleum industry. Between '81 and '86 the petroleum industries R&D had dropped more sharply in Alberta than elsewhere in Canada, a decrease of 62.5% compared to the national figure of 34%. However, overall expenditures by Alberta did not decline on the same scale as the petroleum industries.

The surge in research activities by the services and other manufacturing industries minimized the effect of the fluctuating petroleum industry expenditures. The service industries in Alberta exceeded the national growth in rate, escalating 345% between '81 and '86. Service industry research accounted for 40 cents of every '86 intramural research dollar, up from about eight cents of the '81 dollar. Research expenditures by Alberta's manufacturing industries (excluding refined petroleum) grew three times as fast as the national rate for this period. In '81 the manufacturing industries were performing five cents of every industry research dollar in Alberta; that rose to 17 cents by '86.

In the national context, Alberta's firms funded and performed 6.2% of total industry R&D for '86. The greatest impact of Alberta performers is in fossil fuels research, 48% of which occurred in Alberta. Firms in this province accounted for two % of other manufacturing and 10% of service industries research. Comparisons with other provinces are presented in Table IX.

The clustering of the industry people engaged in R&D parallels the expenditures. For example, 46% of the research staff of the mining and oil wells industries and eight % of the service industries staff are employed in Alberta.

It should be noted that the geographic pattern of industry R&D is influenced by the location of the firms participating in the survey. Thus, the 1986 results may understate the R&D investments of regions and industries.

TABLE IX
Concentration of Industry R&D by Special Industry Group as a % of Total R&D 1986

Province	Resource Based			Other Manufac-turing	Services
	Mining, Metals, & Minerals	Wells & Petro	Wood Based		
Atlantic	X	X	X	1	4
Quebec	25	X	43	X	21
Ontario	59	41	22	67	53
British Columbia	X	X	29	X	9
Alberta	X	48	X	2	10
Manitoba & Saskatchewan	3	X	X	2	3

X - not disclosable by Statistics Canada

OUTPUTS OF INDUSTRY R&D

There is a conceptual, if not demonstrable, link between industry R&D activities and the manufacture of new products or implementation of new processes. On this basis, international trade statistics are regarded as an indicator of the productivity of R&D investments and the competitiveness of a nation's industries. International trade statistics are especially relevant to products that embody a high level of innovative technology. Table X captures trends in selected "R&D intensive" products.

TABLE X
Trends in Exports and Imports of "R&D Intensive Products" by Product Groups, 1978 to 1986

	1978	1980	1982	1984	1986	
			($ in millions)			
Aerospace	804	1,566	2,094	2,078	3,168	exports
	835	1,808	1,468	2,126	2,940	imports
Computers & Related	502	853	1,108	1,765	1,882	
	937	1,743	2,715	4,223	4,263	
Electronic	109	217	260	698	793	
	256	718	771	1,644	1,656	
Telecommunications	416	836	1,170	1,867	1,717	
	620	840	955	1,380	1,784	
Scientific Instruments	303	536	615	840	901	
	1,048	1,480	1,641	2,134	2,311	
Chemicals (Including Drugs)	621	952	861	1,093	1,621	
	856	1,099	1,202	1,610	1,708	
Electrical Machinery	209	317	353	432	519	
	647	751	844	1,012	1,148	
Non-electrical Machinery (motor vehicles)	1,211	644	1,261	2,449	2,272	
	1,965	2,062	2,357	3,491	4,075	
TOTAL	**4,175**	**5,911**	**7,723**	**11,222**	**12,874**	**exports**
	7,164	**10,501**	**11,953**	**17,621**	**19,885**	**imports**

The aerospace and telecommunications product groups are the strongest performers, displaying a positive or marginally negative balance of trade throughout the 1980s. It is not mere coincidence that these two industries have the highest ratio of R&D expenditures to sales among Canada's manufacturing industries.

The overall deficit in trade in high technology products is due largely to computers, electronics equipment, and scientific instruments. The desirability of competitive industries in these strategic technologies is obvious. As essential inputs to modern processing, production, and services industries, a close relationship between manufacturers and industrial customers is needed to ensure the rapid development of appropriate equipment.

Nonetheless, strong imports in computers, electronic equipment, scientific instruments and telecommunications may be a favourable indicator of the national demand for these products by other manufacturing sectors as productivity/competitiveness enhancements.

Another view of Canada's trade in R&D intensive products is given in Table XI. Imports and exports of R&D products are compared to other manufactured goods and natural resource products. In this table, the product groups are presented as a percentage of Canada's total imports and exports for the year. It is apparent that "R&D intensive" products form an increasing portion of both exports and imports. The data suggests that exports of R&D intensive products have increased as a percentage of total exports every year while the share of imports of these products has decreased slightly over the last two years. Imports of other manufactured goods have a higher rate of growth than exports. In the natural resources products, there has been comparable decreases in both imports and exports.

TABLE XI
Trends in Trade in "R&D Intensive", Natural Resources, and Other Manufactured Goods, 1978-1986

Year	R&D Intensive		Natural Resources*		Other Manufactured Goods	
	Exports	Imports	Exports	Imports	Exports	Imports
	(percentage of total exports/imports)					
1978	7.8	14.6	61.4	37.8	30.7	47.6
1980	7.7	15.5	67.0	42.6	25.3	46.9
1982	9.1	17.9	60.9	38.1	30.0	44.4
1984	10.0	19.2	55.0	33.1	35.0	47.7
1986	10.6	18.0	50.2	29.8	39.2	52.2

* natural resources materials include food, energy materials, wood products, metals and minerals, chemicals and fertilizers. (Bank of Canada Series B1051 - B1077)

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Industry Research and Development Activities 1986

R&D in Petroleum Industry, 1988 Estimates (Science Statistics, Vol. 11, No. 11)

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